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ABSTRACT

This document presents a report of the Computer Aids for Chemical Engineering Education (CACHE) Committee concerned with references to previously measured physical properties. A partial list of data that are of use to the chemical engineer is assembled in three tables. References are listed by title, author, publisher, and date. Following each reference is a brief description of the reference. Data regarding identifying properties, critical constants, reaction rate constants, and hazardous or toxic properties are included in the compilation. Types of substances included in the reference are indicated by code letters. References have been divided into the categories of handbooks, general data tabulations, and reference sources. All references are annotated. (EB)

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CACHE

PHYSICAL PROPERTIES DATA BOOK

August 1972

SE 016 816

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I. INTRODUCTION

One of the key aspects in almost all engineering problems is the specification of the physical properties of the materials order consideration. The physical properties of interest may range from the "strength" of a new composite, to the electrical properties of a semi conductor, to the solution properties of a complex mixture of organic liquids. The engineer in general, and the chemical engineer in particular, is responsible for being able to obtain and use a wide range of physical property information. There are many sources of such information. Although the large majority of this information derives originally from laboratory measurements, it has become possible to predict many physical properties on the basis of molecular theories and some description of the atomic structure of the compound in question. This report, however, will deal almost entirely with physical property data which has its foundation in laboratory measurements.

Fortunately, it is rarely necessary to do a complete literature search for physical properties. Many such searches have been performed and the results published in the form of data compilations. There has, however, been such a rapid growth of these compilations in the recent years that a real need exists for a guide to these compilations. This report is an attempt to provide just such a guide.

This report is the first of several reports planned by the

CACHE Committee Physical Properties subgroup and will deal primarily with the question of where to locate previously measured physical properties. Other reports of the subgroup will deal with correlation of physical properties; computer aided physical property estimation, and computer systems for physical property retreival.

II. USING THE GUIDE

A partial list of the data compilations which are of use to the chemical engineer has been assembled in the three tables which form the core of this report. Because of the vast number of such compilations that exist it would be impossible to include each and everyone. Rather an attempt has been made to include those compilations which appear to be of greatest use to chemical engineers. The references are listed by title, author, publisher, and date. Following each reference is a brief description of the reference which is meant to be helpful in evaluating its usefulness.

To the right of each reference are thirteen columns which describe the type of property presented in each compilation. In each column there are one or more code letters which indicate the kind of substance for which those properties are presented. The properties indicated by the columns are:

1. Identification Properties: Melting point, refractive

index, molecular weight, etc.

2. Critical Constants: P_c, T_c

3. Volumetric Properties (pressure, volume, temperature)

4. Thermodynamic Properties (heat capacities, enthalpies, entropies, etc.)

5. Vapor Pressures: (pure component) and latent heats of vaporization.

6. Vapor-Liquid Equilibrium (both high and low pressure)

7. Solubilities (liquid-liquid, or solid-liquid)

8. Gas Solubilities

9. Transport Properties (viscosities, thermal conductivities, diffusivities, emissivities, etc.)

10. Thermochemical Properties (Gibbs free energies, entropies, and enthalpies of formation)

11. Reaction Rate Constants

12. Electrical and Magnetic Properties

13. Hazardous or Toxic Properties

The types of substances included in the reference are indicated by one or more of the following code letters:

HC - Hydrocarbon Fractions

O - All other Organics

In - Inorganics (non-metallic)

G - Gases

M - Metals & Alloys

P - Polymers

X - All of the above

Thus for example if one were seeking enthalpies and volumetric behavior of methane, he would scan down columns 3 and 4 looking for those references with an HC or X indication. Those references with the HC or Y in columns 3 and 4 would be likely sources for the required information. It is unlikely the information could be found in any other sources listed in the tables.

The list of references has been divided (somewhat arbitrarily) into three major subcatagories as listed below:

1. Handbooks: These are usually readily available and commonly contain a wide range of physical properties for a large number of materials. For casual use these data are often of sufficient accuracy. However, these data are often old and of unknown precision. Thus for more exacting work the handbook data are often of questionable value.

2. General Data Tabulations: These often cover a broad range of information and substances. They tend to be more current than the handbooks and frequently contain only critically evaluated data. For more exacting uses these compilations are probably the best source of physical property data.

3. Reference Sources: These entries fall primarily into two catagories: a. Indexes to compilations and b. literature surveys for very specific properties. As a general rule of thumb, the indexes to compilations are probably the first place

for the serious searcher to look. The literature surveys are also useful but in many cases lead to large quantities of unevaluated data which may require extensive screening before use.

GUIDE TO T.E.D. DATA COMPILATION

EC - Hydrocarbon Fractions
O - Other Organics
In - Inorganics (non-metallic)
G - Gases
M - Metals and Alloys
P - Polymers
X - All of the Above

	1. Identifying Properties (melting Pt, R.I., M.W.,etc	2. Critical Constants	3. Volumetric Properties (P, $\bar{V}$, T)	4. Thermodynamic Properties (C_p, $\bar{H}$, $\bar{S}$, etc.)	5. Vapor Pressures	6. Vapor-Liquid Equilibriu	7. Solubilities (Liquid Liquid or Solid-Liquid)	8. Gas Solubilities	9. Transport Properties (μ, D, k, ε)	10. Thermochemical Properties ($\Delta\bar{G}_f$, $\Delta\bar{H}_f$,$\bar{S}_f$)	11. Reaction Rate Constants	12. Electric Properties	13. Hazardous or Toxic
Part I--HANDBOOKS													
1. "American Inst. Physics Handbook" 2nd ed.--D. E. Gray et al, McGraw Hill Book Co., New York (1963). Although primarily designed for physicists, this book contains much useful property data--particularly at extreme conditions.													
2. "Beilstein's Handbuch der Organischen Chemie" H. G. Boit et al, Springer Verlag, Berlin (1918 to Current) contains identification properties for nearly every known organic compound. For help in locating a specific compound see "A Programmed Guide to Beilstein's Handbook" by Olaf Ranquist, Minneapolis, Burgess (1966).	EC, O												
3. "Chemical Engineers Handbook" 4th ed., R. H. Perry et al, McGraw Hill Book Co. New York (1963). Section 3 contains a large quanity of physical property data. Data also scattered throughout sections 12, 13, and 14. Index is rather incomplete so that locating specific information is often a major task.	X	X	X	X	X	X	X	X	X	X	X	X	X

4.	"Corrosion Handbook" Herbert Uhlig, John Wiley & Sons New York (1948). The classic source of information concerning corrosion and rates of corrosion in metallic systems. The book contains extensive references to the pre 1948 literature on corrosion.											M			
5.	"Encyclopedia of Polymer Science and Technology" Vol. 1-15, H. F. Mark et al., John Wiley & Sons New York (1964-71). Series of 15 volumes dealing with all aspects of polymer science and technology. Contains little physical property data per section, but does include some descriptions of particular polymers.	P								P		P	P		
6.	"Engineering Design for Plastics" by E. Baer. (Soc. Plast. Engin.). Reinhold Pub. Co., New York (1964). Designed primarily as a reference book of physical (but not thermal) properties of interest to those who design and fabricate plastics.	P			P			P	P	P			P		
7.	"Gmelins Handbuch Der Anorgischen Chemie" 8th ed, many volumes, various authors, Verlag Chemie, Leipzig (1963). A thorough compilation of the physical properties of inorganic compounds.	M, In, G	M, In, G	M, In, G	M, In, G	M, In, G		M, In, G		M, In, G	M, In, G		M, In, G		
8.	"Handbook of Chemistry" 10th ed. by Norbert A. Lange, McGraw Hill Book Co. New York (19). Broad range of compilations of physical property data. Book is quite similar in many ways to the Handbook of Chemistry and Physics listed below.	X	X	X	X	X	X	X	X	X	X	X	X	X	

9.	"Handbook of Chemistry and Physics" 53rd ed.--R. C. Weast et al, The Chemical Rubber Co. Cleveland, Ohio (1972). Probably one of the broadest compilations of physical property data available. Index well done and easy to use. Volumes change little from year to year and hence earlier editions are also quite useful. Over fifteen thousand compounds are listed.	X	X	X	X	X	X	X	X	X	X	X	X	X
10.	"Handbook of Compositions at Chemical Equilibrium" C. R. Nodding & G. M. Mullet, Interscience, John Wiley & Sons New York (1965). Provides tables of computer output of the equilibrium conditions for various model chemical reactions as a function of the feed distribution, equilibrium constant, and reaction stoichiometry. No new equilibrium constants are reported. These must be known before the tables can be used.													
11.	"Handbook of Natural Gas Engineering" D. L. Katz et al. McGraw Hill Book Co. New York (1959). Presents procedures for conducting engineering calculations for design of equipment to produce and deliver natural gas. Includes some physical property data on hydrocarbon gas. These are not new data, and are not a central part of the book.		HC	HC	HC	HC	HC		HC					
12.	"Handbook of Thermophysical Properties of solid Materials" Vol. 1-5, A. Goldsmith et al., Armour Res. Fund, Materials Laboratory, Wright Air Force Development Center. Pub.	M,In, P		M,In, P	M,In, P	M,In, P		M,In, P			M,In, P	M,In, P	M,In, P	

	by the McMillan Co. New York (1961). Compiles all physical properties of solids reported in literature between 1940-1960. Property variations with temperature are reported by means of graphs.												
13.	"Kirk-Othmer Encyclopedia of Chem. Technology" 2nd ed., H. F. Mark et al. Interscience, John Wiley & Sons New York (1968). The various sections dealing with specific industrial chemicals often include physical property tabulations for that chemical.	X	X	X	X	X	X	X	X	X	X	X	X	X
14.	"Liquid Metals Handbook" (and supplements) U. S. Atom. Energy Commission, Washington, D. C. (1950). Contains information on physical, thermodynamic and thermochemical properties of the liquid metals and many of their compounds.	M	M	M	M	M				M	M	M		
15.	"Metals Reference Book" 3rd Vol., 4th ed. by Colin Smithells, Plenum New York (1967). Contains a wealth of physical property data on metals, alloys, and fused metal salts. Well laid out and easy to use.	M		M	M	M		M	M	M	M		M	
16.	"The Merck Index, an Encylcopedia of Chemicals and Drugs" 8th ed. P. G. Stecher, ed., Merck & Co., Rahway, N.J. (1968) contains identification properties for about 10,000 chemical compounds.	O,In, G												
17.	"Nuclear Engineering Handbook" by H. Etherington, 1st ed., McGraw Hill Book Co. New York (1958). Deals primarily with the problems of		M,G	M,G	M,G	M,G				M,G				M

	nuclear power generation. Includes some physical properties of reactor coolants and fuels.													
18.	"Polymer Handbook" ed. by J. Bandrup & E. H. Immergut, J. Wiley & Sons Inc. New York (1966). This book contains a wealth of information about the physical properties of various industrially important polymers.	P		P	P					P		P		
19.	"Processing of Thermoplastic Materials" ed. by E. C. Bernhardt, Reinhold Pub. Co. New York (1959). Included within this book is a section describing the properties of many industrial polymers withing the temperature ranges commonly encountered in polymer processing.				P					P				

Part II
GENERAL DATA TABULATIONS

1.	"Applied Hydrocarbon Thermodynamics" Wayne C. Edmister, Gulf Pub. Co. Houston Texas (1961). Although intended to teach applications of thermodynamics to petroleum processing, this book also contains extensive physical property data on hydrocarbons.		HC	HC	HC	HC	HC		HC					
2.	"Azeotropic Data" parts I & II by L. H. Horsley & W. J. Tamplin. Advances in Chem. Series, Amer. Chem. Soc. Wash. D.C. (1952, 1962). Presents most of the available literature on azeotropic vapor-liquid equilibrium data. No evaluations of the data are presented.					HC,O, In								
3.	"Chemical Process Principles Charts" O. A. Hougen et. al., John Wiley & Sons, New York (.95) contains various selected property charts that are meant to be used in solving problems in the parent book "Chemical Process Principles".			HC, O,G	HC, O,G									
4.	"Chemical Thermodynamics of Organic Compounds" by D. R. Stull et. al., John Wiley & Sons Inc. New York (1969). Presents zero pressure gas and liquid energy functions (C_p, S, H, and G). Properties are in tabulated form and have been obtained from smoothing extensive collections of published raw data. Some 918 compounds are considered in the temperature range 298-1000°K.	HC, O	HC, O		HC, O		HC,O				HC, O			
5.	"Contributions to the Data of Theoretical Metallurgy" U. S. Bureau of Mines. Bulletins 383, 393, 406, 434, 476, 477, 542, 584. A series of	M,In	M,In	M,In	M,In	M,In				M,In	M,In		M,In	

	monographs covering a wide range of compounds (mostly inorganic) in addition to metals.												
6.	"Critical Constants of Organic Substances" A. P. Kudchadker et al. Chemical Reviews, 68, p. 659-735 (1968). Critical evaluation of the published critical constants for 329 substances. (Essentially all known critical constant literature for organic compounds).		X										
7.	"Dangerous Properties of Industrial Materials" 3rd ed, by N. I. Sax, Reinhold, New York (1968). As name implies, this book is dedicated to describing the dangerous properties of various industrially encountered compounds.	X											X
8.	"Data Book on Hydrocarbons" by J. B. Maxwell, D. vanNostrand Co., New York (1950). Presents much physical property data on hydrocarbons. However, much of the data is now out of data and more current sources are recommended.	HC	HC	HC	HC	HC			HC				
9.	"Dictionary of Organic Compounds" 4th ed., vols. 1-5 plus supplements, by I. Heilbron & H. M. Banbury, Oxford Univ. Press, New York (1965). Presents identification properties for some 12,000 organic compounds.	HC, O											
10.	"Diffusion in Polymers" ed. by John Crank & Geoffrey Park, Academic Press, New York (1968). Although meant primarily to discuss diffusion theory for polymers, this book also presents a great quantity of data on the								HC,O, G,P				

diffusivity of various gases and liquids through polymers.													
11. "Distillation Equilibrium Data" by Ju-Chin Chu, Reinhold Pub. Corp., New York (1950). Presents vapor-liquid equilibrium data for many industrially important systems.					HC, O	HC, O							
12. "Equilibrium Ratio Data Book" Nat. Gasoline Supplymen's Assoc., Tulsa, Oklahoma (1957). Presents graphs of K values as functions of P, T, and convergence pressure for many paraffins and common petroleum impurities.						HC							
13. "Estimation of Thermodynamic Properties of Organic Compounds" by G. J. Janz, Academic Press, New York (1958). Contains essentially no original data, but does provide numbers from which various thermochemical properties of complex molecules may be estimated by means of group contribution theories.				HC,G, O						HC,G, O			
14. "International Critical Tables of Numerical Data; Physics, Chemistry, and Technology" 7 vols. + Index, ed. by E. W. Washburn, McGraw Hill Book Co., New York (1926-1930). One of the earlier attempts to publish critically evaluated physical property data.	X	X	X	X	X	X	X	X	X	X	X	X	X
15. "JANAF Tables" 2 vols. + 3 supplements, prepared under U.S. A.F. Contract AF04(611)-11201 FO4611-67-C-0009 by D. R. Stull, Director. Thermophysical Research Laboratories, Dow Chemical Company, Midland, Mich.		In,E, G		In,E, G	In,E, G					In,E, G			

	(1965-1968). The most complete compilation of material available on chemical equilibrium and thermo chemical properties. Values reported for temps. between 0°K and 6000°K. May be purchased as computer tapes directly from Dow Chem. Co. More recent edition published in June 1971 as part of the Nat. Bur. Stds., NSRDS--#37.														
16.	"Landolt-Bornstein Zahlenwerte und Funktionen" 6th ed., ed. by J. Bartels, et. al., Springer Verlag, Berlin (1960). A German equivalent of the Int. Crit. Tables. Considerably more current than ICT. English subtitles on many graphs and tables.	X	X	X	X	X		X		X	X	X	X		
17.	"Limits of Flammability of Gases and Vapors" H. F. Coward & G. W. Jones, U.S. Bureau of Mines Bulletin 503 (1952). Presents flammability limits for 155 volatile substances.														HC O,
18.	"Liquid-Liquid Equilibrium" by A. W. Francis, Interscience, John Wiley & Sons, New York (1963). In addition to a relatively detailed discussion of the theory of liquid-liquid systems, this book contains an extensive bibliography of references to liquid-liquid systems whose behavior has been described in the open literature. Almost 800 systems are referenced.							HC, O, In							
19.	"Liquid-Vapor Equilibrium in Mixtures of Light Hydrocarbons" M. W. Kellog Co. (1950). Contains 276 pages of graphical solutions to the B-W-R equations for vapor-liquid equilibrium in hydrocarbon mixtures.					HC, G	HC, G		HC, G						

20.	"Mass Transfer in Heterogeneous Catalysis" by C. N. Satterfield, MIT Press, Cambridge, Mass. (1970). Discusses in great depth the role of diffusion in determining the kinetics during heterogeneous catalysis.											HC, G,O			
21.	"Matheson Gas Data Book" 4th ed. Matheson Co. Inc., Rutherford, N.J. (1966). Presents vapor pressures and other thermodynamic data for approximately 130 common industrial gases.	HC, G,In	HC, G,In	HC, G,In	HC, G,In	HC, G,In							HC, G,In	HC G,	
22.	"National Standard Reference Data Series" Collection of monographs published by Nat. Bureau of Standards. Each volume covers its subject in great detail including critical evaluation of each data source. Values actually reported are of the highest possible reliability. This is clearly the place to begin in many physical property searches.	HC, O,In, M,G	HC, O,In, M,G	HC, O,In, M,G	HC, O,In, M,G	HC, O,In, M,G			HC, O,In, M,G	HC, O,In, M,G	HC, O,In,	HC, O,In, M,G	HC, O,In, M,G		
23.	"Oxidation Potentials" 2nd ed. by W. M. Latimer, Prentice Hall Inc. Englewood Cliffs, N.J. (1952). One of the classic reference sources for electrochemical data.											O,In, G,M			
24.	"Phase Equilibrium in Multicomponent Systems" by L. S. Palatnik, & A. I. Landau. Translated by J. Joffe, Holt, Rinehart & Winston Co. Inc. New York (19).						HC, O,G								
25.	"Physical and Azebtropic Data" by G. Claxton. National Benzole and Allied Prods. Assn. London England (1958). Contains little new information,	HC, O					HC, O								

	rather most data have been obtained from larger compendia such as Horseley's book on "Azeotropic Data".													
26.	"Physical Constants of Hydrocarbons C_1 to C_{10}" ASTM Special Publication #109A, Amer. Soc. Test. Mat'ls, Philadelphia, Pa (1963). Most of the data presented have been extracted from API project 44.	HC	HC	HC	HC									H
27.	"Physical Properties of Chemical Compounds" Vol. I-III, by R. R. Dreisbach. Advances in Chemistry Series (#15, 22, 29), American Chemical Society (1955-1961). Contains a large wealth of physical property data. Each compound has its own page, and is cross referenced in an index included in Vol. III. Some estimated or interpolated values are presented in addition to the raw data.	HC, O,G, In	HC, O,G, In	HC, O,G, In	HC, O,G, In	HC, O,G, In		HC, O,G, In		HC, O,G, In	HC, O,G, In		HC, O,G, In	H C I
28.	"Physical Properties of Hydrocarbons" Vol. 1&2 by R. W. Gallant, Gulf Publishing Company. Presents physical property data in the form of extensive charts. Most charts based on actual data, but estimation techniques have been used where data was lacking.	HC	HC	HC	HC	HC				HC				
29.	"Physical Properties of Molecular Crystals, Liquids, and Glasses" by A. A. Bondi, John Wiley & Sons Inc. New York (1968). This book develops and discusses generalized correlations for predicting the properties of many solids in terms of their molecular structure. These, are strictly predictive and in many cases of unknown accuracy. However, in many cases, this may still be the best			P,In	P,In	P,In	P,In			P,In				

	available for many solid materials--especially non-standard ones.												
30.	"Physico-Chemical Constants of Binary Systems in Concentrated Solutions" Vol. I-IV, by J. Timmermans. John Wiley & Sons, New York (1959-60). Presents an extremely comprehensive compilation of physical property data on binary mixtures gathered from the literature.	HC, O, In, G				HC, O, G, In	HC, O, G, In	HC, O, G, In	HC, O, G, In	HC, O, G, In			
31.	"Physico-Chemical Constants of Pure Compounds" Vol. I & II, by J. Timmermans, Elsevier Pub. Co. Inc. New York (1950, 1965). Physical property data for hundreds of compounds are presented and critically evaluated.	HC,O	HC,O	HC,O	HC,O	HC,O				HC,O			HC,O
32.	"Pressure-Volume-Temperature Relationships of Organic Compounds" 3rd ed., by R. B. Dreisbach, Handbook Publishers Inc. Sandusky, Ohio (1952). Presents vapor pressure--temperature charts for many organic compounds. Compounds are grouped by class, and "Cox Charts" presented for each class.					HC,O							
33.	"The Properties of Gases and Liquids" by T. Sherwood and R. Reid. McGraw Hill Book Co., New York (1958). Presents a critical review of estimation procedures for a limited number of properties of gases and liquids. Comparisons of experimental and estimated values are shown in the form of tables in order to show the reliability of the various estimation procedures. Recommendations are made regarding the best methods for estimating each property or extrapolating available data.		HC,G In,O	HC,G In,O	HC,G, In,O	HC,G, In,O				HC,G, In,O	HC,G, In,O		

34.	"Saturated Liquid Densities of Oxygen, Nitrogen, Argon, and Para Hydrogen" Nat. Bur. Stand. Tech. Note 361 Wash., D.C. (1968).		G	G		G								
35.	"Selected Values of Properties of Chemical Compounds" Formerly a research project of the "Manufacturing Chemists Association. The project has now been merged with API project 44 and both are being continued at the Thermodynamics Research Center, Texas A&M University, College Station, Texas.	O,In, G	O,In, G	O, In, G	O,In, G	O,In, G				O,In, G	O,In, G			
36.	"Selected Values of Properties of Hydrocarbons and Related Compounds" American Petroleum Institute Project 44. Although an initial report was available in 1953 through Carnegie Press, this project is continuing and the data are updated frequently. Current work in progress at Thermodynamics Research Center, Texas A&M University, College Station Texas. This work deals primarily with thermodynamic and thermochemical properties of hydrocarbon gases, and is probably the most reliable data of its type.	HC,O	HC,O	HC,O	HC,O	HC,O				HC,O	HC,O			
37.	"Selected Values of Thermodynamic Properties" F. D. Rossini et. al. Nat. Bureau Stand. Circular 500, Washington D.C. (1952). Contains zero pressure thermodynamic and thermochemical data for several thousand compounds between 0 and 6000°K.		HC,O In,G		HC,O In,G	HC,O, In,G					HC,O In,G			
38.	"Selected Values of Thermodynamic Properties of Metals" by R. Hultgren et. al., John Wiley & Sons Inc. New York (1963). Data have been collected	M			M	M							M	

	from an exhaustive search of the pre 1963 literature.													
39.	"Solubilities of Inorganic and Metal Organic Compounds" Vol. I and II, 4th ed. by W. F. Linke, D. Van Nostrand Co, New York (1958, 1965). This book is a continuation of the compilation of Seidell (referenced below) first published in 1967. The newer versions have been vastly improved and updated.					HC,O, In,G	HC,O, In,G	HC,O, In,G	HC,O, In,G					
40.	"Solubilities of Inorganic and Metal Organic Compounds" 3rd ed., Vol. 1 & 2, by A. Seidell D. Van Nostrand Inc., New York (1940-41). A extensive compilation of quantitative solubility data taken from the periodical literature.					HC,O, In,G	HC,O, In,G	HC,O, In,G	HC,O, In,G					
41.	"Solubilities of Organic and Inorganic Compounds" Vol. I, Pts. 1 & 2 (Binary systems), Vol. II, Pts. 1 & 2 (Multi-component systems) MacMillan Co. New York (1963). Translated from the original Russian. Similar to Seidell's work listed above.					HC,O, In,G	HC,O, In,G	HC,O, In,G	HC,O, In,G					
42.	"Solvents Guide" by C. Marsden & S. Mann, Interscience, John Wiley & Sons, New York (1963). A compilation of properties of some 300 different solvents is given. For each solvent a simple table of the physical properties and characterististics is given along with vapor pressures, densities, etc.	HC,O, In		HC,O, In		HC,O, In		HC,O, In						H I
43.	"Specific Heats and Enthalpies of Technical Solids at Low Temperatures" Nat. Bur. Stands. Monograph 21,				M,In									

	Washington, D.C. (1960). The data reported herein have been compiled from the open literature.												
44.	"Survey of Solubility Diagrams for Ternary and Quarternary Systems" Spec. Publication #50, Bur. Engin. Res. Univ. of Texas, Austin, Texas, by D. M. Himmelblau, B. L. Brady, & J. J. McKetta.							HC,O, In					
45.	"Tables Annuelles de Constantes et Donnes Numeriques de Chemie, de Physique, et de Technologie" L' Association Internationale... VII Congress de Chimie Appliquee. These tables represent an early French attempt to evaluate and tabulate all available physical property data. Efforts continued until about 1945. Succeeded in some sense by the National Bureau of Standard's NSRDS.	X	X	X	X	X	X	X	X	X	X	X	X	)
46.	"Tables of Bi Molecular Gas Reactions" Nat'l. Bur. Standards NSRDS #9, Washington, D.C. (1967). One of the NSRD Series. This volume deals with reaction rate constants for Bi Molecular gaseous reactions.											G,HC		
47.	"Tables of Chemical Kinetics Homogeneous Reactions" Nat. Bur. Standards Curcular 510 Washington, D.C. (1951) + Supplement (1956). This volume contains a compilation or critically evaluated reaction rate data.											HC,O In,G		
48.	"Tables of Thermodynamic and Transport Properties of Air, Argon, Carbon Dioxide, Carbon Monixide, Hydrogen,			G	G					G				

	Nitrogen, Oxygen & Steam" by J. Hilsenrath et. al. Pergamon Press New York (1960). Essentially the same data as presented in N.B.S. circular 564 in 1955, but slightly updated. Excellent source for compounds listed.												
49.	"Technical Data Book--Petroleum Refining" American Petroleum Institute, Division of Refining, New York (1971). Extensive physical property tabulations and correlations for hydrocarbons and other organics.		HC,O	HC,O	HC,O	HC,O				HC,O			
50.	"Thermal Conductivity" Vols. 1 & 2 by R. P. Tye, Academic Press, New York (1969). Although very little data is actually presented, this book delves in great detail into the problems associated with the experimental measurement of thermal conductivities.									X			
51.	"Thermal Conductivity" National Bureau of Standards Special Publication #302, Washington, D.C. (1968). Proceedings of the seventh conference. (No published proceedings for the previous 6 conferences). Deals primarily with the thermal conductivities of metals and metal oxides. Data reported as tables and graphs.									In,M			
52.	"Thermal Conductivities of Gases and Liquids" by N. V. Tsederberg MIT Press, Cambridge, Mass. (1965). Although primarily useful as a source book for measurement techniques, this book does present a fair number of thermal conductivity correlations as well as references to the original data.									HC,G In,O			

53. "Thermal Conductivities of Selected Materials" NSRDS #16, National Bureau of STandards, Washington, D.C. (1968). Part of the NSRD series dealing solely with thermal conductivities. Data are presented for twelve metallic elements, a range of graphites and three fluids (acetone, ammonia and methane) in the gaseous state.									In,M, G				
54. "Thermochemical Kinetics, Methods for Estimation of Thermokinetic Data and Rate Parameters", by S. W. Benson, John Wiley & Sons, New York (1968). In addition to the estimation procedures, this book includes extensive tables of numerical data in the appendix.											HC,O, In		
55. "Thermochemistry of Petrochemicals" by K. Kobe et. al., this rather extensive series of articles in Petroleum Refiner. (1949-58) presents thermochemical data (heat capacities, enthalpies, as well as free energies and enthalpies of formations) for many hydrocarbons, hydrocarbon derivatives, and other species of interest to the petrochemical industry.				HC,O, G						HC,O, G			
56. "Thermodynamic Charts for Combustion Processes" Vol. 1 & 2 by H. C. Hottel, McGraw Hill, New York (1949). Contains many charts showing equilibrium constants and other thermodynamic properties as functions of temperature for combustion reactions. These are now outdated, and the more recent JANEF and API 44 Tables are to be preferred.				HC,G, In,G, M						HC,O, In,G, M			
57. Thermodynamic Data Refined for L. P.		HC	HC	HC	HC								

G." Series of articles by K. E. Starling & Y. C. Kwok in Hydrocarbon Processing (March--July 1971). Although no new data are reported, an extensive search and evaluation of the existing literature went into the preparation of these articles. It appears these may well represent the most reliable thermodynamic properties available for L. P. G. compounds. It is anticipated that a book which includes essentially the same information as these articles will be published shortly.													
58. "Thermodynamic and Reduced Correlations for Gases" by F. S. Manning & L. N. Canjar Gulf Publishing Corp. Houston, Texas (1967). Contains mollier charts and tables of thermodynamic functions for approximately 20 commonly encountered gases (mostly of interest to the petroleum and related industries).		HC,G	HC,G	HC,G	HC,G								
59. "Thermodynamic Functions of Gases" Vols. I, II, III, by F. Din, Butterworth Scientific Publications, London (1956). Covers the compounds: Ammonia, Carbon Dioxide, Carbon Monoxide, Air, Acetelene, Ethylene, Propane, Argon, Methane, Ethane, and Nitrogen. Presents some of the best thermodynamic data available at publication time for these compounds.	G	G	G	G	G								
60. "Thermodynamic Properties of Hydrocarbons" by L. N. Canjar. Series of articles in Hydrocarbon Processing (Aug. 1962--Jan. 1963) and "Thermodynamic Properties of Non-Hydrocarbons" by L. N. Canjar & F. S.		HC,G	HC,G	HC,G	HC,G								

	Manning. Series of articles in Hydrocarbon Processing (Jan.--April 1966). These articles contain essentially the same information as in the previously referenced book by the same authors.		HC,G	HC,G	HC,G	HC,G								
61.	"Thermodynamic Properties of Refrigerants" Amer. Soc. Heat, Refrig.,Air Cond. Engin., New York(1969). Property tables and diagrams are presented for about 35 commonly encounted refrigerants.		G	G	G	G								
62.	"Thermodynamic Properties of Sixty Five Elements, Their Oxides, Halides, Carbides and Nitrides". U. S. Bureau of Mines, Bulletin 605. Presents data on the heat capacity, enthalpy, heats of formation and Gibbs free energy of formation for 65 metallic elements, their oxides, halides, carbides and nitrides. Temperatures usually range from 298°K ~ 2000°K. Results presented both as graphs and analytic functions of temperature.				M,In						M,In			
63.	"Thermodynamic Properties of Steam" by J. H. Keenan & F. G. Keyes, John Wiley & Sons, New York (1936). This is the original "steam tables". Recently been superceded by more accurate compilations, but still a fine piece of work.		G	G	G	G								
64.	"Thermodynamic Properties of the Elements" by D. R. Stull, and G. C. Sinke. Advances in Chemistry Series, Vol. #18, American Chemical Society, Washington, D.C. (1956). Presents critically evaluated thermodynamic properties for the elements, but no compounds.	In,G, M	In,G, M	In,G, M	In,G, M	In,G, M								

65. "Thermophysical Properties Research Center Data Series" (Purdue University) Vol. 1-13, edited by Y. S. Touloukian, Plenum Publ. Corp. New York (1969 and later).														
V1: Thermal Conductivity of Metallic Elements and Alloys										M				
V2: Thermal Conductivity of Non-Metallic Solids										In				
V3: Thermal Conductivity of Non-Metallic Liquids and Gases										In,O, G				
V4: Specific Heat of Metallic Elements and Alloys				M										
V5: Specific Heat of Non-Metallic Solids				In										
V6: Specific Heat of Non-Metallic Liquids and Gases				In,O, G										
V7: Thermal Radiative Properties of Metallic Elements and Alloys										M				
V8: Thermal Radiative Properties of Non-Metallic Solids										In				
V9: Thermal Radiative Properties of Coatings										In				
V10: Thermal Diffusivity										HC,O				
V11: Viscosity										In,G				
V12: Thermal Expansion of Metallic Elements and Alloys			M											
V13: Thermal Expansion of Non-Metallic Solids			In											
This massive series contains both original data obtained at TPRC and critically evaluated data from the literature.														
66. "Vapor-Liquids Equilibrium Data" by Ju-Chin Chu, J. W. Edwards, Inc., Ann Arbor, Mich. (1956). Book contains vapor-liquid data for many					HC, O,In, G	HC, O,In, G								

industrially important mixtures.													
67. "Vapor-Liquid Equilibrium Data" by Buford D. Smith, Director, Thermodynamics Research Laboratory, Washington Univ., St. Louis, Mo. (1968 and on). Data have been collected from an extensive search of the literature. Data are critically evaluated and presented in tabular form.				HC,O, In,G	HC,O, In,G	HC,O, In,G							
68. "Vapor Pressures of Organic Compounds" by T. E. Jordon, Interscience, John Wiley & Sons, New York (1954). Vapor pressures for about 1200 organic and metal organic compounds are presented as functions of temperature. Numerical data, graphical correlations, and analytical correlations are presented. Data have been obtained from the pre 1954 literature.					O,HC, M								
69. "The Virial Coefficients of Gases, A Critical Compilation" by J. H. Dymond & E. B. Smith, Claredon, Oxford Univ. Press, London (1969). Second and Third virial coefficients are presented for about 275 pure gases.			HC,G, O,In										

Part III REFERENCE SOURCES												
1. "Annotated Acession List of Data Compilations of the Nat. Bur. Stands. Office of Standard Reference Data", National Bureau of Standards Technical Note 554, Washington, D.C. (1970). An index to the NSRDS. Clearly a most useful reference source.	X	X	X	X	X	X	X	X	X	X	X	X
2. "Bibliography of Chemical Kinetics and Collision Processes" ed. by A. R. Hochstim, IFI/Plenum, New York (1969). An annotated bibliography of gas phase reaction rates for atoms, ions and small molecules. Contains about 27,000 entries from 7,000 references from the world literature of the period 1900-1966.											HC,O, In,G	
3. "Bibliography for Physical Behavior of Hydrocarbons Under Pressure" by D. L. Katz and M. J. Rzasa, J. W. Edwards Inc., Ann Arbor (1946). Presents an exhaustive bibliography of all references in the pre 1946 literature which deal with the physical properties of hydrocarbons and their mixtures. An excellent introduction to the older literature.		HC	HC	HC	HC	HC	HC	HC				
4. "Bibliography of Hydrocarbons" by J. A. Muckleroy, Nat. Gas Processors Assoc., Tulsa, Oklahoma (1962). Continues the Katz-Rzasa bibliography to cover the period 1946-1960.		HC	HC	HC	HC	HC	HC	HC				
5. "Bulletin of Thermodynamics and Thermochemistry" by E. F. Westrum Jr., an annual publication of the International Union of Pure and Applied Chemistry. Each article contains an index to the current literature on	HC,O, In,G	HC,O, In,G	HC,O, In,G	HC,O, In,G	HC,O, In,G		HC,O, In,G		HC,O, In,G	HC,O, In,G	HC,O, In,G	HC,O, In,G

	physical properties. It is planned to update the published tables in API 44 on the basis of the data referenced in these articles.												
6.	"Comprehensive Index of API 44--TRC Selected Data on Thermodynamics and Spectroscopy" Staff, Texas A & M Publication 100, Thermodynamics Research Center, TRC Data Distribution Office, College Station, Texas (1969).		HC,O, In,G	HC,O, In,G	HC,O, In,G	HC,O, In,G					HC,O, In,G		
7.	"Consolidated Index of Selected Property Values" Publication 976, Office of the Critical Tables, National Academy of Sciences, Nat. Res. Council, Washington, D.C. (1962). Presents an index of substances and properties located in the following compilations prepared for the O.C.T.: 1. API Research Project 44 2. Man. Chem. Assoc. Res. Proj. 3. NBS Circular 500 4. "Thermodynamic Properteis of the Elements" by Stull & Sinke 5. Bureau of Mines Bulletins 383, 384, 393, 406, 407, 477, 542, 584 6. "Selected Values of Thermodynamic Properties of Metals and Alloys" pub. by Mineral Research Laboratory, Univ. of California. This reference is clearly one of the first places to begin looking for much physical property information.	X	X	X	X	X	X	X	X	X	X	X	X
8.	"Encyclopedia of Hydrocarbon Compounds" Vols. 1-13, edited by J. E.	HC											

	Faraday and A. S. Freeborn, Chemical Publishing Co., Inc. New York (1956 and later). Mostly helpful in identifying chemical compounds--combines the literature references found in Beilstein, British Abstracts, Chem. Abstracts, and Chemsche Zentralblatt.													
9.	"Literature Survey of Solubility Parameters for Ternary and Quarternary Liquid Systems" by M. R. Fenske, Petrol. Refining Laboratory, Penn State University, State Park, Penna.						HC, In,O							
10.	"Liquid-Liquid Equilibriums" by A. W. Francis, Interscience, John Wiley & Sons, New York (1963). Provides references to approximately 4000 immiscible liquid systems.						HC,O, In							
11.	"Solubilities of Gases in Liquids" by R. Battino and H. L. Clever, Chemical Reviews, Vol. 66, #4, p 395-463 (1966). Provides an exhaustive cross referenced index to the original gas solubility (in liquids) literature. Also provides a guide to the reliability of each of the individual references.							HC,O, G						
12.	"Thermophysical Properties Research Literature Retrieval Guide" 2nd ed., Vols. 1-3, Y. S. Touloukian et. al., Plenum Pub. Co., New York (1967). These volumes cite all literature references to experimental data on thermal conductivity, heat capacity, viscosity, emissivities and adsorbtivities, diffusion coefficients, thermal diffusivities and Prandtl numbers for the period 1920 to June 1964.			X					X					

13.	"Vapor-Liquid Equilibrium" by E. Hala et. al. Pergamon Press, New York (1967). Presents an exhaustive literature survey of available vapor-liquid equilibrium data up till May 1965. Data are listed by compound and cross referenced. Both binary and multicomponent data are covered.						HC,O, In,G							
14.	"Vapor-Liquid Equilibrium Data at Normal Pressures" by E. Hala et. al., Pergamon Press, New York (1971). A continuation and updating of the original book by Hala et.al.						HC,O, In,G							

OTHER COMPENDIA OF PHYSICAL PROPERTY DATA

Because of the amount of effort currently being expended both in this country and abroad, one can anticipate continued rapid growth in both the quality and quantity of physical property data that will be available in the coming years. In anticipation of these events several scientific societies, and national governmental agencies have established programs for the evaluation and tabulation of physical property data. These programs are briefly reviewed below:

1. CODATA: Committee on Data for Science and Technology. The Committee on Data for Science and Technology (CODATA) was established by the Eleventh General Assembly of the International Council of Scientific Unions (ICSU) in January of 1966. The committee was to promote and encourage the production and distribution of tabulations of critically selected physical property data on substances of interest to the scientific and technical community. This group has recently published the "International Compendium of Numerical Data Projects" (published by Springer-Verlag, New York (1969)). This compendium contains descriptions of currently available compilations of critically evaluated data, a list of those groups which are continuing efforts along these lines, and guidelines for the production of future data compilations. Clearly this volume is a valuable extension of the information presented herein.

Several nations are members of the CODATA Committee and as part of their national membership have established national CODATA Committees. In 1969 the six nations with such committees were Canada, Germany, Japan, the Soviet Union, the United Kingdom and the United States.

2. IUPAC: Thermodynamics Tables Project Center. The Thermodynamics Tables Project Center was established by the Commission on Thermodynamics and Thermo Chemistry of the International Union of Pure and Applied Chemists in 1964. Its goal is to prepare universally accepted tables of physical and transport properties of simple fluids. The project is under the direction of Dr. Selby Angus, and is located in the Imperial College, London. This project is limited to only the properties of gases and liquids, and then to temperatures below which dissociation effects begin to be important. Tables of numerical values, rather than correlation equations are being prepared because it is felt that it is easier to agree on numerical values than on correlation equations. The progress of this project is described in detail in "A Review of the Work of the IUPAC Thermodynamic Tables Project", Dr. S. Angus PCR/17, IUPAC Thermo. Tables Proj. Center, Dept. of Chem. Engin. and Chem. Tech., Imperial College of Science and Technology, London (May 1969).

3. U.S. National Bureau of Standards: National Standard Reference Data System (NSRDS). This program and several of its

reports have already been briefly described in the body of this report. However, the following additional comments appear useful as well: The system is subdivided into seven programs which are concerned with the following groups of properties: 1. nuclear properties; 2. atomic and molecular properties; 3. solid state properties; 4. thermodynamic and transport properties; 5. chemical kinetics; 6. colloid and surface properties; and 7. mechanical properties of materials. Most emphasis in the past has been placed on catagories 2 and 4.

4. The Office of Scientific and Technical Information (OSTI) was established in the United Kingdom in 1965 to oversee and support the collection and publication of technical data tables for the entire scientific and technical community. This office is the primary source of funding for the IUPAC--Thermodynamic Tables Project Center, and annually publishes a list of numerical data projects in the United Kingdom.

5. The State Service for Standard and Reference Data (GSSSD) coordinates and directs research, and disseminates critically evaluated physical property data throughout the USSR scientific and technical community. A network of GSSSD organizations have been formed in the scientific research institutions of ministries, colleges and industry. The task of obtaining the reference data is assigned to these organizations. A summary of the function of the GSSSD is contained in: "Thermophysical

Properties of Gases and Liquids" ed. by V. A. Rabinovich, Publishing House for State Standards, Moscow (1968). A translation of this work is provided by A. Moscona, in the Israel Program for Scientific Translations, Jerusalem (1970).

THE ACCURACY OF REPORTED PHYSICAL PROPERTY DATA

Although a great quantity of physical property data already exists in the literature, much of this data is of unknown quality and accuracy. The question of determining which data are accurate and which are not is a task of tremendous magnitude--usually well beyond the means of a single investigator. Because of the recognized need to establish critically evaluated and accepted standard reference data systems several groups have begun to compile and publish such data. In addition to the five groups listed in the previous section the following organizations in the United States are currently compiling (in some cases also measuring) and publishing critically evaluated physical property data:

6. Thermodynamics Research Center, Texas A & M University, College Station Texas (The continuing API project 44).

7. Office of the Critical Tables, National Academy of Sciences, National Research Council, Washington, D.C.

8. Thermophysical Properties Research Center, Purdue

University, West Lafayette, Indiana.

The data reported by these organizations will usually be of the highest possible reliability and thus is usually the data of first choice when such a choice is available. When data from other sources, particularly those which have not been critically evaluated, is used the user must always bear in mind the possible inaccuracies that may be inherent in these data.